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July 25, 2001

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Ms. Magalie R. Salas
Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

Re: *Ex Parte* Presentation; ET Docket No. 98-153

Dear Ms. Salas:

The U.S. GPS Industry Council ("the Council"), through undersigned counsel, submits for the Commission's consideration in connection with the referenced rulemaking proceeding the enclosed analysis on the use of emissions masks as a means of protecting GPS signals from Ultra Wideband ("UWB") interference. At least one UWB proponent has suggested in this proceeding that the Commission impose an in-band emissions mask on UWB devices to protect the reception of GPS signals in the proximity of UWB devices operating on an unlicensed basis.

As is set out in the enclosed paper, an in-band emissions mask will not protect adequately GPS receivers from UWB interference. Furthermore, the Commission will be under constant pressure to change the mask to accommodate the rise in the noise floor from overlapping large commercial UWB networks operating at high data rates. Past experience shows that under constant pressure from user communities, the Commission will modify technical characteristics in response to public request.

The Council strongly urges the Commission to require that UWB devices operate well outside the GPS band and other "restricted" bands currently allocated for the provision of safety-of-life services, and to adopt an appropriate out-of-band emissions mask.

The Council is prepared to meet with Commission staff to discuss the attached analysis, respond to questions and other concerns.

Respectfully submitted,

Raul R. Rodriguez
Counsel to the U.S. GPS Industry Council

RRR/rjc
Enclosure
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In-Band Emissions (IBE) or Out-of-Band Emissions (OOBE) Mask: That is the Question

Presented by the U.S. GPS Industry Council
Prepared by A. J. Van Dierendonck, AJ Systems

INTRODUCTION

The questions are: 1) "Why is it that a very conservative emissions mask fails to protect Government systems (such as GPS)?" 2) "If these UWB devices are unlicensed (or licensed, for that matter), even with a conservative emissions mask, will they not protect the GPS user -- is there a technical reason?" 3) "Does the emissions mask deal with damage to the noise floor? If you have a very conservative emissions mask, why doesn't this adequately address practical damage to the noise floor?"

These questions have already been answered in a Multispectral Solutions, Inc. (MSSI) submission to the FCC that shows that the spectral characteristics of UWB transmissions cannot be controlled to the level required for spectral overlap with safety-critical services.[1] Edited excerpts from that submission are provided below. After that, reference is made to a recent NPRM published by the FCC that shows the emission mask creep is real and allowed by the FCC.[2] Thus, precedence has already been set, showing that the only way to prevent interference to GPS is to keep the UWB intruders out of the band completely so that UWB can be classified as OOBE with no spectral overlap with safety-critical services.

What this means is that the UWB devices must contain filters that notch out all emissions in the GPS band (as well as in other safety-critical bands).

DISCUSSIONS

Spectral Density Modifications due to Antenna and Near-Field Effects

It has been claimed by some UWB proponents that filtering of the excitation pulse prior to radiation by the antenna to limit the bandwidth of the radiation to an allocated band is undesirable because of the deleterious effects such filtering might have on the transmitted pulse shape. However, as will be shown below, without such filtering, it is virtually impossible to prevent *significant* changes in both frequency and bandwidth with *accidental* changes or simple *external* modifications to the UWB antenna. Such accidental or intentional modifications can be as simple as antenna breakage, bending the antenna, placing a metal plate or object (e.g., pocket calculator, file cabinet, etc.) near the antenna or lengthening (or shortening) the antenna element(s).

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[1] Response to FCC Notice of Proposed Rule Making ET Docket No. 98-153 "Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems," Submitted to Federal Communications Commission, Washington, DC, Multispectral Solutions, Inc., Gaithersburg, MD, 12 September 2000.

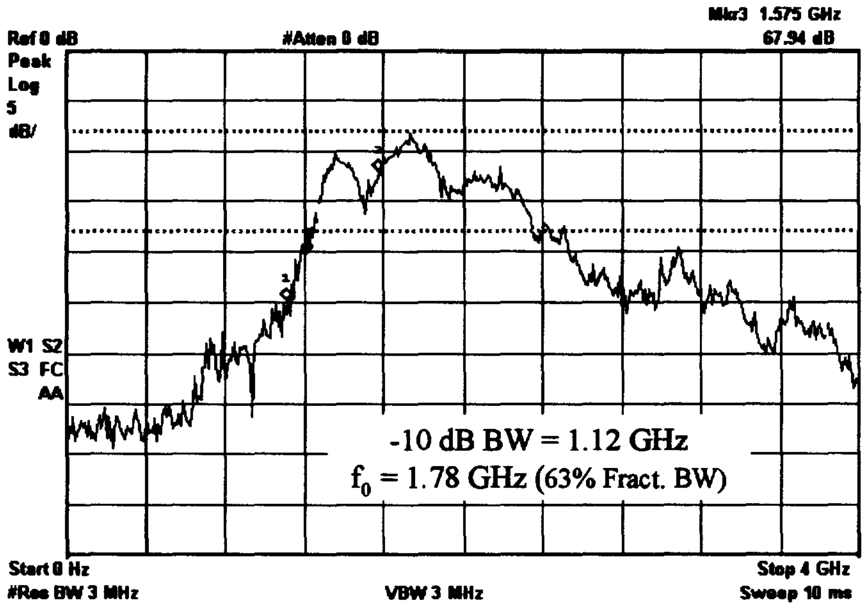
[2] FCC Public Notice DA 00-2317, "Amendment of Part 15 of the Commission's Rules Regarding Spread Spectrum Devices," ET Docket No. 99-231, May 11, 2001.

In the past, the FCC has been concerned with the possibility that a user of a Part 15 device may attempt to replace or modify an antenna. FCC Part 15.203, for example, was established to ensure that no antenna, other than that furnished by the product manufacturer, would be used with a Part 15 device. This is typically accomplished with a permanently attached antenna or through the design of a unique connector, thereby preventing the use of an unauthorized antenna or external power amplifier.[3] For non-UWB devices, however, modifications to an *existing*, manufacturer-supplied antenna do not typically result in the generation of out-of-band emissions. Unfortunately, as demonstrated below, UWB systems which utilize non-filtered, impulse excited antennas can be easily altered or tampered with to produce significantly narrower band emissions at other than the "design" frequency, and with power levels many dB higher than those contained in the original, unmodified emissions. The following figures illustrate this problem.

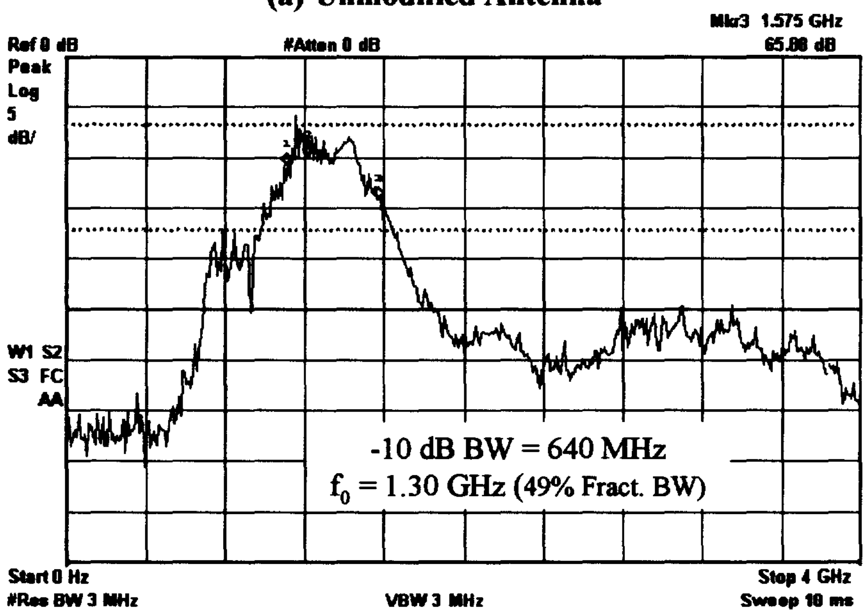
Figure 1(a) shows the measured output of a wideband, cylindrical dipole antenna that is tuned or "cut" for a center frequency of 2 GHz. The -10 dB bandwidth of this emitter is 1.12 GHz for a fractional bandwidth of 63%. The center frequency, as measured by the arithmetic average of the two -10 dB intercepts, is measured to be 1.78 GHz. In Figure 1(b), the same antenna was modified by attaching a small metal tube as an extension to one of the radiating elements of the dipole. Note that the center frequency shifted downwards by nearly 500 MHz, and the bandwidth similarly was reduced by nearly 500 MHz thereby producing dramatic changes to the unit's operational characteristics. The energy is now more highly concentrated in the spectral region containing both GPS L2 (1227.60 MHz) and L5 (1176.45 MHz) frequencies. Note that *significant* operational parameter changes occurred with the UWB emitter by simply lengthening one element of the broadband antenna – an operation that can be performed without replacement of the existing antenna. Note that an identical effect is observed if one accidentally breaks one end of a longer broadband dipole antenna.

A second example is illustrated in Figure 2 below. Figure 2(a) shows the spectral content of a UWB emitter that uses a broadband "bow-tie" patch antenna. The patch antenna is a printed structure that is totally encapsulated in plastic, making it difficult for a user to physically lengthen or shorten the antenna as in the previous example. The -10 dB bandwidth of the source is 1.86 GHz, yielding a very broad operational fractional bandwidth of 114%. Figure 2(b) illustrates the effect of bringing a small piece of copper foil (approximately 2" x 2.5") into close proximity to the bow-tie radiator. Note that the results are even more dramatic than those shown in Figure 1. Here, the bandwidth dropped by nearly 1.5 *GHz* (to a resultant 29% fractional BW), while the center frequency shifted lower by 230 MHz. The particular copper "parasitic patch" chosen for this experiment happened to be resonant near 1.4 GHz; however, it is easy to see that by choosing different dimensions for the copper foil, one can essentially tune a spectral peak to sensitive frequency bands such as GPS, PCS/PCN and various TV channels. Note also that the spectral peak associated with these modified emissions increased by 10 dB.

[3] Due to the popularity of MMCX, MCX, and reverse polarity SMA, BNC and TNC type antenna connectors, the FCC through a Public Notice DA 00-1087 dated May 22, 2000 (as clarified on June 22, 2000) no longer allows their use as of October 1, 2000. This action further demonstrates the FCC's desire to prevent unwanted modifications or changes to Part 15 radiating elements.

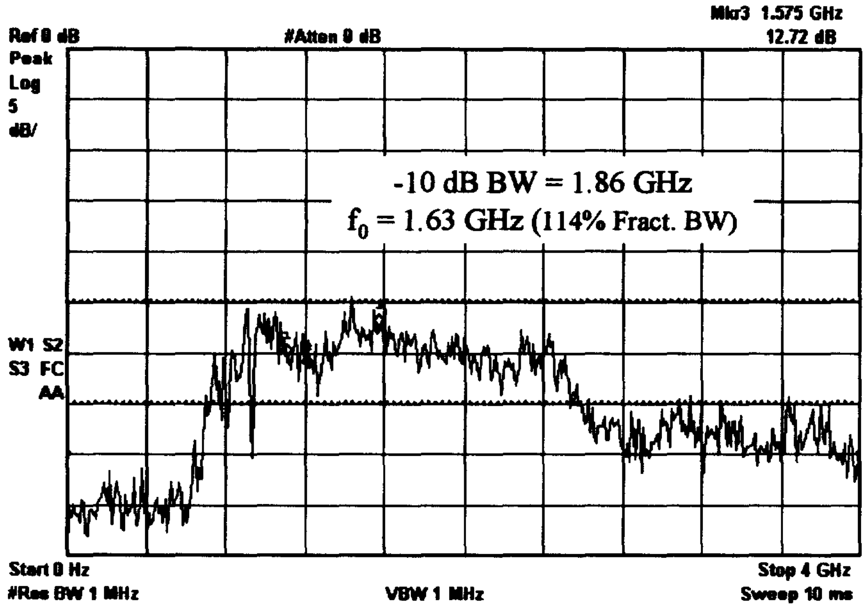


(a) Unmodified Antenna

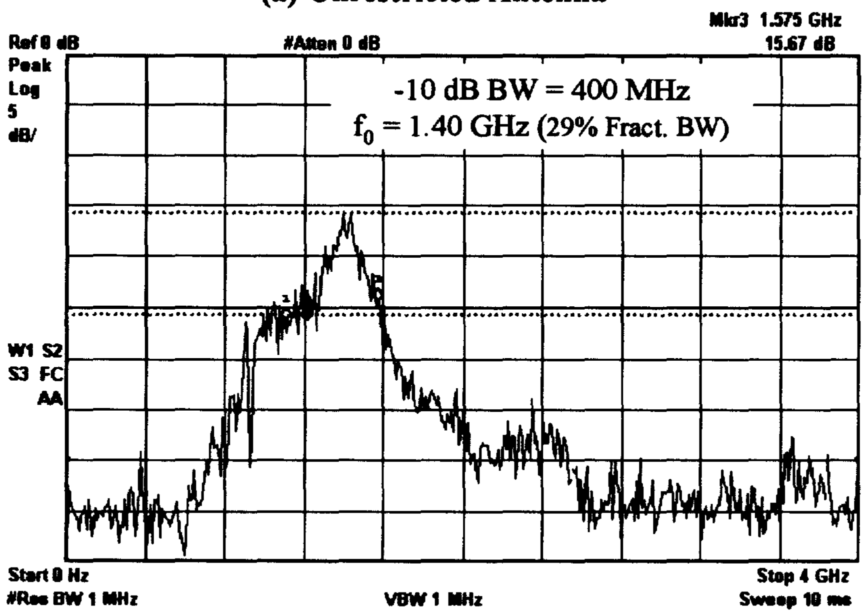


(b) Single Lengthened Element

Figure 1. Wideband Cylindrical Dipole



(a) Unrestricted Antenna



(b) Antenna with 2"x2.5" Parasitic Copper Plate

Figure 2. Wideband "Bow-Tie" Antenna

Similar effects will occur if such an antenna is brought in close proximity to *any* metal object or object containing metalization – e.g., pocket calculator, watch, file cabinet, etc. Thus, while one may design a completely enclosed, printed circuit antenna, the parasitic effects of nearby metal objects can significantly alter radiated bandwidth, center frequency and emission levels.

In the above examples, the antennas were directly excited by a wideband impulse having the following properties:

UWB Source: MSSI TFP-1000 (S/N 001)[4]

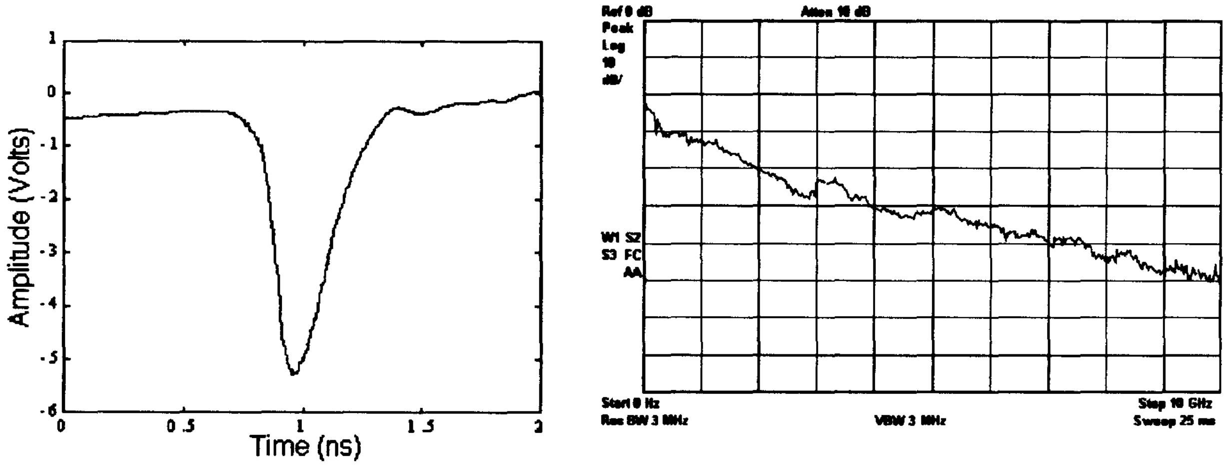
Rise Time: 269 ps

Fall Time: 127 ps

Width (RMS): 245 ps

Peak-to-Peak output: 5.39 V.

Figure 3 below illustrates both the time- and frequency-domain responses of this short pulse excitation.



(a) Time Domain Waveform **(b) Frequency Domain Response**

Figure 3. UWB Impulse Source (MSSI TFP-1000 S/N 001)

Note that the measured spectral content of this pulse extends from DC to beyond 10 GHz. These "doubly-exponential" pulses are readily generated with fast rise time digital circuits and minimal additional components making them very attractive for low cost UWB applications.

Another proposed wideband pulse excitation[5] is that of the theoretical "Gaussian monocycle" which has the mathematical relationship

$$p(t) = \frac{t}{\tau}\exp\left(-\left(\frac{t}{\tau}\right)^2\right)$$

and resultant Fourier transform

4 This same source was provided to the National Telecommunications and Information Administration (NTIA) for its testing of potential UWB interference effects.

5 Alan Petroff and Paul Withington, "Time Modulated Ultra-Wideband (TM-UWB) Overview," http://www.time-domain.com/Technology/findout_papers.html.

$$P(f) = -j\pi^{3/2}\tau^2 f \exp\left(-\pi^2\tau^2 f^2\right)$$

Obviously p(t) is physically unrealizable as it is anticipatory or non-causal, having an output response for negative time. However, causal approximations to p(t) can be generated with delay. Plots of p(t) and P(f) for a value of τ = 100 ps are shown below in Figure 4.

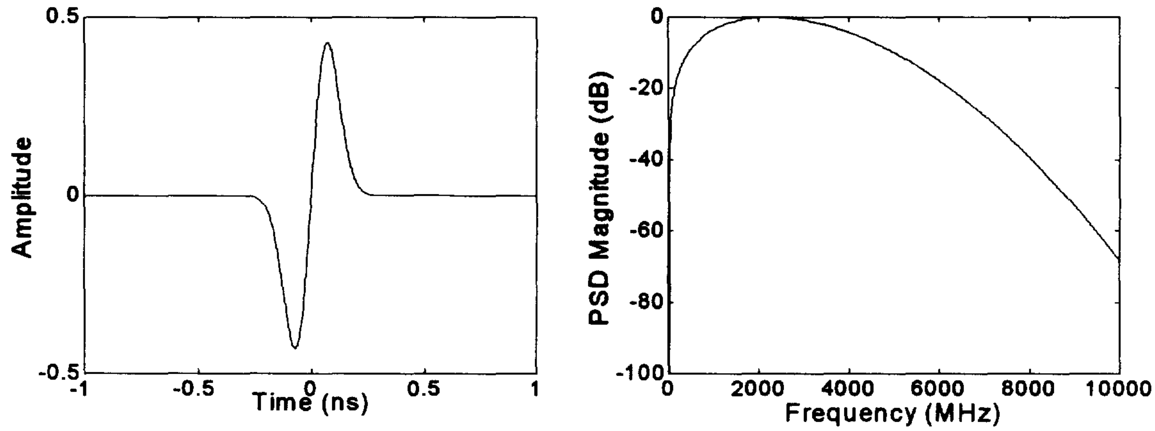


Figure 4. Theoretical Gaussian Monocycle and Power Spectral Density

For this hypothetical waveform, the center frequency is calculated to be 2.47 GHz with a -10 dB bandwidth of 4.02 GHz (-10 dB at 460 MHz and 4,480 MHz), or 162% fractional. Note, again, that the energy density of this excitation pulse covers a very extended frequency range.

Unfortunately, an antenna is a very poor electrical filter, with many natural resonance frequencies (both harmonic and non-harmonic) over a broad frequency range. Thus, the combination of a broadband, unfiltered excitation with an antenna can result in significant energy radiated at other than the antenna's so-called "design" frequency. Two additional examples are illustrated below.

In Figure 5, a commercially available, wideband omni-directional antenna from Tecom Industries, Inc. (Tecom Model B19961-1), designed for the frequency range of 4.4-5.0 GHz, was directly excited by a broadband impulse source. As seen, in addition to the desired output in the 4.4-5.0 GHz region, strong unintended responses at frequencies far removed from the antenna's operational frequency range were observed in the far field of the antenna. In this example, strong outputs were also observed in the GPS bands at L1 (1575.42 MHz), L2 (1227.60 MHz) and L5 (1176.45 MHz). Peak levels out-of-band exceed the in-band levels by over 40 dB.

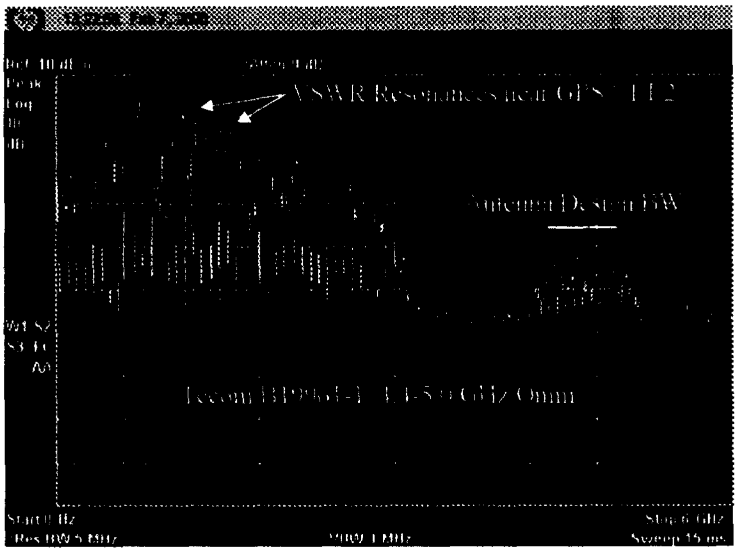


Figure 5. Impulse Excitation of Commercial 4.4-5.0 GHz Omni Antenna (Tecom B19961-1)

Similarly, Figure 6 illustrates the effects of impulse excitation of a broadband (1.5 GHz center frequency, 500 MHz bandwidth) sleeve dipole antenna designed by the Hazeltine-Wheeler Laboratories. Again, energy is radiated at frequencies other than in the antenna's design frequency range.

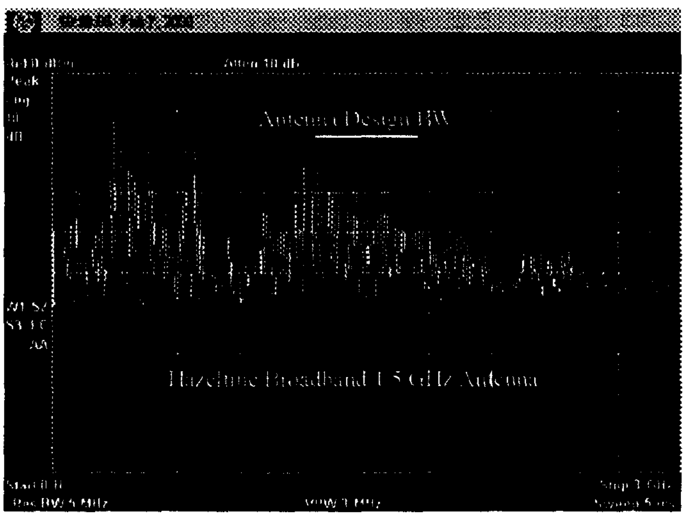


Figure 6. Impulse Excitation of Hazeltine Broadband 1.5 GHz Omni Antenna

<u>Conclusions and Recommendations</u> For UWB systems that utilize unfiltered pulse excitation of an antenna, it is difficult if not physically impossible to preclude the possibility of radiating energy in unintended ways. Such unintended radiation can be caused by either intentional or accidental modifications to the antenna. Unfortunately, the resultant emissions can be far removed from the antenna design frequency.

Furthermore, it was demonstrated that the radiated spectrum of unfiltered systems could easily be modified through damage to the antenna, lengthening or shortening the antenna, or positioning the antenna near any metal object. Unfortunately, the result of such simple operations can be a significant reduction in instantaneous bandwidth with correspondingly increased power densities (Watts/Hz) in unintended regions of the spectrum.

Only pulse filtering *prior* to radiation by the antenna can eliminate these indeterminate, yet potentially interfering, spectral components. For all of the reasons mentioned above, the US GPS Industry Council strongly recommends that the FCC prohibit the use of unfiltered UWB emissions under unlicensed Part 15 regulations and modify the rules to prohibit any emissions in the GPS band. Effectively, this would reclassify UWB emissions as OOBE with a specified OOBE mask.

Spectral Density Modifications due to Rule Modifications

Essentially, the allocated spectrum for UWB is meant to be the *entire* radio spectrum by UWB proponents. Thus, its emissions that at *in-band* to another allocated spectrum, such as that of GPS, would be governed by IBE, or in-band emissions, mask. Such a mask has been proposed by XtremeSpectrum, Inc.[6]. Unfortunately, some entity is always going to want to modify the IBE mask so that their system will work, and, eventually, the FCC will give in and grant their request. This type of happening is very evident from a recent notice released by the FCC regarding devices operating in the 2.4-GHz band.[7] It seems that certain entities want to stretch the definition of spread spectrum to include their signal structures (that are not spread spectrum), and the FCC appears to be open to allowing that to happen. The result is that the spectral characteristics in the 2.4-GHz band are about to change. Thus, precedence is being set. It is obvious that this would also happen in the UWB world if UWB emissions are classified as IBE in the GPS band. Thus, it is imperative that UWB must be classified as OOBE in the GPS band, which means that the allocated spectrum for UWB cannot overlap with GPS.

SUMMARY AND CONCLUSIONS

There are two important reasons why the allocated spectrum of UWB cannot overlap with GPS and simply apply an In-Band Emissions (IBE) mask requirement on the unlicensed UWB. First, the emissions spectral density of UWB cannot be controlled without filtering the UWB pulses before applying them to a transmitting antenna. Second, if the UWB spectrum is defined to overlap the GPS band (with and IBE mask), precedence dictates that there will be a continuous stream of requests to change that mask to accommodate new UWB technologies. Precedence will also dictate that the FCC will grant modifications to the mask to grant those changes.

It is imperative that UWB must be classified as OOBE in the GPS band with a defined OOBE mask. This means that the allocated spectrum for UWB cannot overlap with GPS.

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[6] *Comments of XtremeSpectrum, Inc. On Issues of Interference Into Global Positioning System Receivers* (filed April 25, 2001) and XtremeSpectrum, Inc. presentation (filed on May 30, 2001).

[7] FCC Public Notice DA 00-2317, "Amendment of Part 15 of the Commission's Rules Regarding Spread Spectrum Devices," ET Docket No. 99-231, May 11, 2001.